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Dissertation Outline

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Title: Nonlinear Optical Materials Based on Oligothiophene-Doped Nematic Liquid Crystals Containing Polymer-Grafted Inorganic Nanorods

In the past few decades, there have been several investigations to deliver new optical materials for potential optical applications because the irradiation of a light source can drive those materials. However, the optical nonlinearity of current nonlinear optical materials is not favorable, thus, requiring high light sources to drive those materials. In this presented thesis, the author delivered a new nonlinear optical material with increased sensitivity to low light intensities by incorporating polymer-grafted inorganic nanorods into dye-doped liquid crystals (LCs). This new nonlinear optical material established a new phenomenon that memorized the molecular reorientation of LCs, thus, fabricating a microlens array with selective polarization. This discovery was implemented in delivering a new microlens array with tunable focal length under heat treatment that can be incorporated into future nano-scale optical devices requiring tunable lenses depending on the temperature environment. Therefore, the proposed nonlinear optical material is expected to enhance the current applications in optical switching and introduce a new facile technique to fabricate optical microlenses.

In Chapter 1 “General Introduction”, the author briefly introduced the reported thesis and showed the benefits of enhancing the sensitivity of LCs under the influence of a light source. The author reported past research reports regarding the sensitivity of LCs under an external stimulus by incorporating polymers and nanomaterials. This led to the fabrication of a new nonlinear optical material by incorporating polymer-grafted inorganic nanorods into dye-doped LCs.

In Chapter 2 “Photoinduced Molecular Reorientation of Oligothiophene-Doped Liquid Crystals Containing Inorganic Nanorods”, the author delivered a new nonlinear optical material whose photoinduced molecular reorientation occurred at lower threshold intensities by simply incorporating polymer-grafted zinc oxide (ZnO) nanorods in oligothiophene-doped nematic LC systems. The threshold intensity of the photoinduced molecular reorientation was 39% lower in systems containing inorganic nanomaterials compared to systems with no dopants of inorganic nanomaterials. The effects of the grafted polymer and ZnO nanorod were carefully examined by delivering a polymer-stabilized LC (PSLC) system containing the homopolymer with the same molar fraction as the polymer grafted on the ZnO nanorods. The results suggested that ZnO nanorods have a higher effect than the homopolymer itself because ZnO nanorods assisted in the molecular reorientation of nematic LCs by causing a small disordering and weakening the surface anchoring aided by the grafted polymer.

In Chapter 3 "Spatial Distribution of Polymer-Grafted Nanorods in Oligothiophene-Doped Liquid Crystals Forming Microlenses", the author prepared an innovative approach to deliver nano-scale optical lenses by incorporating polymer-grafted ZnO nanorods at high-weight fractions in oligothiophene-doped nematic LC systems. The photoinduced molecular reorientation of this system was examined and discovered that by irradiating the sample with a polarized laser beam for long periods, the molecular reorientation of the nematic LCs remained permanent, resulting in the memory effect of LC shown by the memorized diffraction rings. The memorized molecular orientation resulted in microlenses with polarization dependency, i.e., an order-to-order molecular orientation of nematic LCs in the microlens. This was compared with the system containing only the homopolymer added in oligothiophene-doped nematic LC systems to remove the effect of the ZnO nanorods. However, no memory effect of the LC was observed for the system containing only the homopolymer. The results suggested that ZnO nanorods stabilized the molecular reorientation of the nematic LCs.

In Chapter 4 "Thermal Control of a Liquid Crystal Microlens Array Embedded in a Polymer Network", the author proposed an innovative technique to fabricate polarizable selective microlens arrays embedded in a polymer network whose focal length can be tuned with temperature changes. A photopolymerizable monomer, a crosslinker, and a photoinitiator were added to an oligothiophene-doped nematic LC system. This system was incorporated with polymer-grafted ZnO nanorods, and a polarizable selective microlens array was fabricated when irradiated with a laser beam at different locations. The focal length of the fabricated microlens array was investigated at various temperatures and discovered that the focal length could be tuned when heated above the phase transition temperature of the nematic LC molecules and consequently cooled down to room temperature. A microlens array containing no polymer-grafted ZnO nanorods was fabricated, and the microlens achieved an order-to-disorder molecular reorientation, i.e., non-polarizable selective microlenses. The study suggested that incorporating polymer-grafted ZnO nanorods assisted and stabilized the molecular alignment of nematic LCs.

In Chapter 5 “Summary”, the author summarized the main points of the presented doctoral dissertation. A new nonlinear optical material was delivered by incorporating polymer-grafted ZnO nanorods in oligothiophene-doped nematic LCs with great miscibility. The polymer-grafted ZnO nanorods enhanced the optical nonlinearity of the nematic LC molecules, thus, lowering the threshold intensity required to induce a molecular reorientation of molecules. Apart from that, the polymer-grafted ZnO nanorods also caused the memory effect of the nematic LC molecules, generating memorized diffraction rings with polarization dependency. This developed a polarization selective microlens array with tunable focal length by incorporating polymer-grafted ZnO nanorods. In summary, the results of this research will open a new further investigation into doping nanomaterials in nonlinear optical materials to enhance their potential applications in optical limiting and optical microlenses.